CLAIMS

What is claimed is:

1. A method of physically spatially switching a small particle to a selected one of plural alternative destination locations, the method comprising:

suspending the particle in fluid flowing in a microfluidic channel from (i) an upstream location through (ii) a junction branching to (iii) each of plural branch channels leading to alternative downstream destination locations; and

manipulating the particle under force of radiation as it moves in the microfluidic channel so as to move into a selected branch channel leading to a selected one of the plural alternative downstream destination locations.

2. The small particle switching method according to claim 1

wherein the manipulating is with a single radiation beam, the particle suspended within the flowing fluid passing straight through the junction into a path leading to a first downstream destination location in absence of the radiation beam but deflecting under radiation force in presence of the radiation beam into an alternative, second, downstream destination location.

3. The small particle switching method according to claim 2

wherein the manipulating is with a selected one of two radiation beams impinging on the junction from different directions, the particle suspended within the flowing fluid deflecting under radiation force of one radiation beam into a first path leading to a first downstream destination location while deflecting under radiation force of the other, different direction, radiation beam into a second path leading to a second downstream destination location.

4. The small particle switching method according to claim 1

wherein the manipulating is with a laser beam.

5. The small particle switching method according to claim 4 wherein the manipulating is with a Vertical Cavity Surface Emitting (VCSEL) laser beam.

6. The small particle manipulating method according to claim 6 wherein the manipulating is with a Vertical Cavity Surface Emitting (VCSEL) laser beam having Laguerre-Gaussian spatial energy distribution.

7. A switching mechanism for a small particle comprising:

a substrate in which is present at least one microfluidic channel proceeding from (i) an upstream location through (ii) at least one junction branching to (iii) each of plural downstream locations, the substrate being radiation transparent at the at least one junction;

flow means for inducing in the microfluidic channel a flow of fluid bearing the small particle; and

at least one radiation beam selectively enabled to pass through the radiation-transparent junction region of the substrate and into the microfluidic channel so as to there selectively produce a radiation force on the small particle as it flows by sufficient so as to move the particle into a selected one of the plural downstream locations.

8. The switching mechanism according to claim 7 wherein the substrate has plural levels differing in distance of separation from a major surface of the substrate, the at least one microfluidic channel branching at the at least one junction between at least (i) one, first, path continuing on the same level and (ii) another, alternative second, path continuing on a different level; and

wherein one only radiation beam selectively acts on the small

particle at the junction so as to (i) produce when ON a radiation force on the small particle at the junction that will cause the small particle to flow into the alternative second path, but which (ii) will when OFF permit the small particle to continue flowing upon the same level and into the first path.

9. The switching mechanism according to claim 7

wherein a selected one of two separately-directed radiation beams acts on the small particle at the junction so as to produce a directional radiation force on the small particle which force causes this small particle to flow into the selected one of the plural downstream locations.

10. The switching mechanism according to claim 7

wherein n different microfluidic channels proceed through the at least one junction so as to collectively branch to each of m different downstream locations;

wherein the small particle appearing at the junction in flow from any of the n different microfluidic channels is acted upon by the radiation beam so as to flow into a selected one of the m different downstream locations.

11. The switching mechanism according to claim 10

wherein two opposed radiation beams selectively pass through the radiation-transparent junction region of the substrate and into the microfluidic channel so as to there selectively produce a radiation force on the small particle as it flows by sufficient so as to move the particle into a selected one of the m different downstream locations.

12. A switch for controllably spatially moving and switching a small particle arising from a particle source into a selected one of a plurality of particle sinks, the switch comprising:

a radiation-transparent microfluidic device defining a

branched microfluidic channel, in which channel fluid containing a small particle can flow, proceeding from (i) particle source to (ii) a junction where the channel then branches into (iii) a plurality of paths respectively leading to the plurality of particle sinks;

flow means for inducing a flow of fluid, suitable to contain the small particle, in the microfluidic channel from the particle source through the junction to all the plurality of particle sinks; and

at least one radiation beam selectively enabled to pass through the radiation-transparent microfluidic device and into the junction so as to there produce a radiation force on a small particle as it passes through the junction within the flow of fluid, therein by this selectively enabled and produced radiation force selectively directing the small particle that is within the fluid flow into a selected one of the plurality of paths, and to a selected one of the plurality of particle sinks;

wherein the small particle is physically transported in the microfluidic channel from the particle source to that particular particle sink where it ultimately goes by action of the flow of fluid within the microfluidic channel; and

wherein the small particle is physically switched to a selected one of the plurality of microfluidic channel paths, and to a selected one of the plurality of particle sinks, by action of radiation force from the radiation beam.

13. The small particle switch according to claim 12

wherein the branched microfluidic channel of the radiation-transparent microfluidic device is bifurcated at the junction into two paths respectively leading to two particle sinks;

wherein the flow means is inducing the flow of fluid suitable to contain the small particle from the particle source through the junction to both particle sinks; and

wherein at least one radiation beam is selectively enabled to

produce a radiation force on a small particle as it passes through the junction within the flow of fluid so as to selectively direct the small particle into a selected one of the two paths, and to a selected one of the two particle sinks.

14. The small particle switch according to claim 12

wherein two radiation beams are selectively enabled to produce a radiation force on a small particle as it passes through the junction within the flow of fluid so as to selectively direct the small particle into a selected one of the two paths, and to a selected one of the two particle sinks, one of the two radiation beams being enabled to push the particle into one of the two paths and the other of the two radiation beams being enabled to push the particle into the other one of the two paths.

15. The small particle switch according to claim 12

wherein the branched microfluidic channel of the radiation-transparent microfluidic device is bifurcated at the junction into two paths one of which paths proceeds straight ahead and another of which paths veers away, the two paths respectively leading to two particle sinks;

wherein one radiation beam is selectively enabled to produce a radiation force on a small particle as it passes through the junction within the flow of fluid so as to push when enabled the small particle into the path that veers away, and so as to permit when not enabled that the particle will proceed in the path straight ahead.

16. The small particle switch according to claim 12

wherein the bifurcated microfluidic channel of the radiation-transparent microfluidic device defines a geometric plane; and

wherein the one radiation beam is substantially in the geometric plane at the junction.

17. Optical tweezers comprising:

a body defining a microfluidic channel in which fluid transporting small particles does flow, the body's microfluidic channel having a branching junction where the body is transparent to radiation; and

a radiation source selectively acting through the body at the junction on the transported small particles within the microfluidic channel so as to cause each particle to enter into a selected branch of the junction.

18. The optical tweezers according to claim 17 wherein the radiation source comprises:

one or more Vertical Cavity Surface Emitting Lasers (VCSELs).

19. The optical tweezers according to claim 18

wherein the one or more Vertical Cavity Surface Emitting Lasers (VCSELs) are arrayed.

20. The optical tweezers according to claim 19

wherein the plurality of arrayed VCSELs are so arrayed in one dimension.

21. The optical tweezers according to claim 19

wherein the plurality of arrayed VCSELs are so arrayed in two dimensions.

22. The optical tweezers according to claim 18

wherein the at least one or more VCSELs emit laser light in the Laguerre-Gaussian mode, with a Laguerre-Gaussian spatial intensity distribution.

23. The optical tweezers according to claim 18 wherein the one or more VCSELs are disposed orthogonally to surfaces of the body in which is present the microfluidic channel, laser light from at

least one VCSEL impinging substantially orthogonally on both the body and its microfluidic channel.

24. The optical tweezers according to claim 17

wherein the microfluidic channel of the body has and presents at a location where impinges the radiation a junction where at least one upstream, input, fluidic pathway bifurcates into at least two alternative, downstream, fluidic pathways;

wherein presence or absence of the radiation at the junction determines whether a particle contained within fluid flowing from the upstream fluidic pathway through the junction is induced to enter a one, or another, of the two alternative, downstream, fluidic pathways.

25. The optical tweezers according to claim 24

wherein the at least two alternative, downstream, fluidic pathways of the microfluidic channel are separated in a "Z" axis direction orthogonal to the plane of the substrate;

wherein the presence or absence of the laser light from the VCSEL at the junction selectively forces the particle in a "Z" axis direction, orthogonal to the plane of the substrate, in order to determine which one of the two alternative, downstream, fluidic pathways the particle will enter.

26. The optical tweezers according to claim 24

wherein the at least two alternative, downstream, fluidic pathways of the microfluidic channel are separated in different directions in the plane of the substrate, the at least two alternative downstream, fluidic pathways being of the topology of the arms of an inverted capital letter "Y", or of the two opposing crossbar segments of an inverted capital letter "T";

wherein the presence or absence of the laser light from the VCSEL at the junction selectively forces the particle to deviate in direction of motion in the plane of the substrate, therein to

determine which branch one of the two alternative, downstream, fluidic pathways the particle will enter.

27. The optical tweezers according to claim 17

wherein the body's junction branches into at least m alternative, downstream, fluidic pathways where $m > 3$;

wherein presence or absence of the radiation at the junction determines whether a particle contained within fluid flowing from the upstream fluidic pathway through the junction is induced to enter a one, or another, of at least four alternative, downstream, fluidic pathways.

28. A method of optically tweezing a small particle comprising:

transporting the small particle in fluid flowing within a microfluidic channel; and

manipulating the small particle with Vertical Cavity Surface Emitting Laser (VCSEL) laser light as it is transported by the flowing fluid within the channel.

29. The method of optically tweezing a particle according to claim 28

wherein the producing is of laser light having a substantial Laguerre-Gaussian spatial energy distribution.

30. The method of optically tweezing a particle according to claim 27 extended and expanded to

illuminating a plurality of particles each in an associated microfluidic channel each in the laser light of an associated single Vertical Cavity Surface Emitting Lasers (VCSEL) all at the same time.

31. The method of optically tweezing a particle according to claim 27

wherein laser light illumination of the particle moving in the

microfluidic channel under force of fluid flow is substantially orthogonal to a local direction of the channel, and of the particle movement.

32. A microfluidic device for sorting a small particle within, and moving with, fluid flowing within microfluidic channels within the device, the microfluidic device comprising:

a housing defining one or more microfluidic channels, in which channels fluid containing at least one small particle can flow, at least one microfluidic channel having at least one junction, said junction being a place where a small particle that is within a fluid flow proceeding from (i) a location within a microfluidic channel upstream of the junction, through (ii) the junction to (iii) a one of at least two different, alternative, microfluidic channels downstream of the junction, may be induced to enter into a selected one of the two downstream channels;

flow means for inducing an upstream-to-downstream flow of fluid containing the at least one small particle in the microfluidic channels of the housing and through the junction; and

optical means for selectively producing photonic forces on the at least one small particle as it flows through the junction so as to controllably direct this at least one small particle that is within the fluid flow into a selected one of at the least two downstream microfluidic channels;

wherein the at least one small particle is transported from upstream to downstream in microfluidic channels by the flow of fluid within these channels; and

wherein the at least one small particle is sorted to a selected downstream microfluidic channel under photonic force of the optical means.

33. The small particle microfluidic sorting device according to claim 32

wherein the junction is in the topological shape of an

inverted "Y" or, topologically equivalently, a "T", where a stem of the "Y", or of the "T", is the upstream microfluidic channel, and where two legs of the "Y", or, topologically equivalently, two segments of the crossbar of the "T", are two downstream microfluidic channels.

34. The small particle microfluidic sorting device according to claim 32

wherein the junction is in the shape of an "X", where two legs of the "X" are upstream microfluidic channels, and where a remaining two legs of the "X" are two downstream microfluidic channels.

35. The small particle microfluidic sorting device according to claim 32

wherein the optical means produces photonic pressure force that pushes the at least one small particle in a selected direction.

36. The small particle microfluidic sorting device according to claim 32

wherein the optical means produces a radiation beam that enters the junction from a direction substantially orthogonal to the microfluidic flow paths at the junction.

37. The small particle microfluidic sorting device according to claim 32 wherein the optical means comprises:

a laser.

38. The small particle microfluidic sorting device according to claim 37 wherein the laser comprises:

a Vertical Cavity Surface Emitting Laser (VCSEL).

39. The small particle microfluidic sorting device according to

claim 38

wherein the VCSEL produces a radiation beam that enters the junction from a direction substantially orthogonal to the microfluidic flow paths at the junction.

40. The small particle microfluidic sorting device according to claim 38

wherein the VCSEL produces a radiation beam that enters the junction from a direction substantially in a plane established by the microfluidic flow paths at the junction.

41. The small particle microfluidic sorting device according to claim 32

wherein the housing defines a plurality of microfluidic channels each with at least one junction;

and wherein the optical means comprises:

an array of laser light sources operable in parallel to each selectively illuminate an associated junction so as to selectively cause at the same time various small particles that are moving through various of the junctions to controllably enter into a selected one of at least two microfluidic channels downstream of each junction.

42. The small particle microfluidic sorting device according to claim 41 wherein the array of laser light sources comprises:

an array of Vertical Cavity Surface Emitting Lasers (VCSELs).